Two-pass 3-D Prestack Depth Imaging of the SEG Salt Model Data

Walter Kessinger, Houston Advanced Research Center (HARC)

SUMMARY

Two-pass 3-D prestack depth imaging is an approximation to one-pass 3-D prestack depth migration of seismic data. The two-pass method offers significant advantages in terms of greatly reduced computational requirements, simpler data manipulation and faster imaging turn-around. However, the two-pass processes involves an unavoidable loss of accuracy when applied in areas with significant velocity variations in the cross-line direction. Here I apply two-pass 3-D prestack depth imaging to the SEG salt model data. Despite the limitations of the method, this study confirms that it is a fairly robust tool for defining complicated salt structures.

INTRODUCTION

Two-pass prestack depth imaging can significantly reduce the time and expense required for prestack processing of seismic surveys because of the greatly reduced computational cost of the method when compared to 3-D depth migration. Furthermore, the flexibility of the method makes it useful for a variety of different imaging strategies. As a stand-alone application, the two-pass method can be used as a reconnaissance tool for "quick-look" depth imaging of a profile through a 3-D survey. It also makes it possible to experiment with various processing schemes, imaging parameters or velocity models in areas of complex structure, without a large-scale processing commitment. For these reasons alone, the two-pass method should be a standard tool for seismic processors.

Two-pass prestack depth imaging can also be used to streamline model building for 3-D imaging of large surveys. This involves using the two-pass method for iterative imaging and model building of a number of sections throughout a volume, then interpolating a 3-D velocity model from the individual velocity sections. The resulting model can subsequently be used for either poststack or prestack 3-D depth migration, or with the two-pass method for full-volume prestack depth imaging at relatively modest expense.

Of course, two-pass depth imaging is an approximate method; appropriate application should be constrained by an understanding of its limitations. The method implicitly assumes that velocity complications are predominately in the in-line direction. This assumption is frequently not justified, particularly for allochthonous salt bodies. However, this geological setting is precisely where the flexibility of the two-pass method offers the most significant benefits as a velocity model building tool.

In this study, the two-pass method is applied to the computational SEG salt model dataset. Because the model is known exactly, the imaging results can be used to develop a qualitative measure of the accuracy of two-pass prestack depth imaging when applied to data that strongly violate the assumptions of the method.

TWO-PASS PRESTACK DEPTH IMAGING

In the two-pass method, cross-line prestack time migration is followed by 2-D prestack depth migration in the in-line direction. The cross-line time migration acts to remove, or greatly reduce, sideswipe energy from outside each 2-D in-line plane, and improves the signal strength of desirable reflectors by focusing energy spread throughout a survey into the in-line plane. The effect of the cross-line migration is to produce a regularized 2-D prestack line which has been decoupled from the full 3-D survey and can subsequently be processed as an independent dataset. Iterative 2-D prestack depth migration and velocity analysis can be applied to 2-D datasets produced by cross-line migration.

The cross-line migration used in this study was implemented by Jeno Gazdag using equations formulated by Gerry Gardner (Devaux et al., 1996). It uses a Kirchhoff time migration operator and an RMS velocity function to project each sample of each input trace of a 3-D survey into a desired 2-D prestack dataset.

SEG SALT MODEL

This experiment used 3-D acoustic computational data produced by four of the U.S. National Laboratories. The data were generated using a model of a fictitious but realistic allochthonous salt structure designed by a committee of the Society of Exploration Geophysicists. Compressional wave velocities in the model were chosen to be representative of seismic velocities in the Gulf of Mexico.

Figure 1 shows a map view of the salt model. A plunging feeder stock is a significant feature in the northwest. Towards the middle of the salt body, the salt has migrated up the upthrown side of a NW dipping fault plane, forming a dome. Southeast of the dome, the salt forms a faulted sill, with limited areas of extreme rugosity in its upper surface. As is the case with many allochthonous salt bodies, this structure cannot be simply described in terms of strike and dip directions; however, the acquisition grid is oriented 45° to the principal direction of salt migration.

The dense grid of plus signs in Figure 1 are source locations for the phase C data acquisition. Within this grid, there are 50 "sail lines" with a cross-line spacing of 160 meters. Each line has 95 source events, with a shot spacing of 80 meters.

The data subset I used for this study is known as C3-NA. This subset was intended to represent a standard marine acquisition geometry, i.e., a narrow azimuth, towed cables dataset, where all lines were acquired from west to east. Each sail line has 8 streamers, with a maximum in-line offset of 2680 meters and a 40 meter group spacing. Twenty meter by 20 meter CMP bin coverage yields a nominal fold of 17.

TWO-PASS RESULTS

I used two-pass prestack depth imaging to produce twelve sections through the SEG salt model at cross-line spacings of 300 meters. For the cross-line migration, I used the average RMS velocity in the sediment areas of the model, i.e., away from the salt. In-line data constructed by cross-line migration were then prestack depth migrated using the exact velocity model at that location.

Overall, the two-pass method greatly exceeded expectations. Figures 2 and 3 show the two-pass images of sections 340 and 385, respectively. In sections 340 and 385, top and base of salt are clearly imaged and correctly positioned. The coherency and positioning of subsalt reflectors in these two sections is fairly poor, however.

On one of the twelve sections, the two-pass method failed to properly image the base of salt. Figure 4 shows the two-pass migration result for this section, which was line 400. Figure 5 shows the velocity model for line 400. This section is nearly centered with respect to the salt structure.

I found it interesting that the two-pass method would perform so well on section 385, and relatively poorly on line 400, given that they are fairly similar sections only 300 meters apart. To investigate further, I repeated the two-pass procedure for line 400 using a different velocity function for the cross-line migration. Rather than use an average sediment velocity function which excluded areas of salt "contamination," I used a function which was an average of all locations over the salt.

Figure 6 shows the two-pass image from this last experiment. Imaging at base of salt is improved, but it is still not as good as in the other ten sections. Also, the top of salt is now contaminated by sideswipe energy, although probably not enough to produce an erroneous interpretation. The dipping sediment reflectors around the salt also show some sensitivity to the change in cross-line migration velocity.

CONCLUSIONS

My results show that it is possible to define the top and base of a complicated salt body using two-pass prestack depth imaging. Over most of the model, the method did surprisingly well and produced sharp, unambiguous images of the top and base of salt. However, the method had difficulty imaging base of salt across a 500 meter wide area under the center of the salt structure.

By performing the cross-line migration using salt-contaminated velocities, I was able to somewhat improve the base of salt imaging in this problem area. However, this involved a trade-off, in that it introduced positioning errors in the top of salt image. Finally, the two-pass method was unable to image below salt reflectors in the SEG salt model.

ACKNOWLEDGMENTS

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REFERENCE

Devaux, V., Gardner, G. H. F., and Rampersad, T., 1996, *3-D prestack depth migration by Kirchhoff operator splitting*: Expanded Abstracts, 66th Annual SEG International Meeting and Exhibition, 455-458.

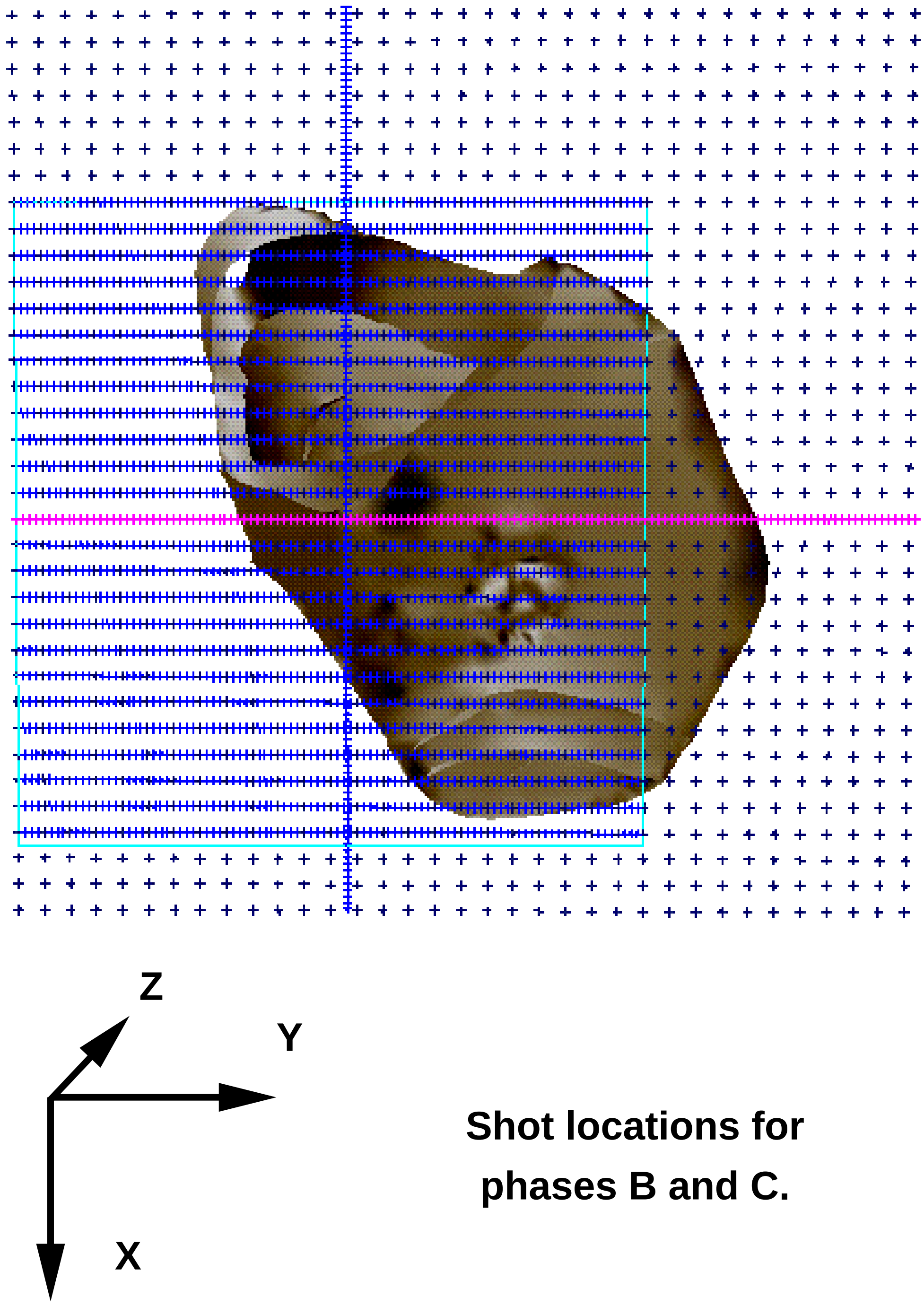

Figure 1: Map view showing the extent of the salt in the SEG/EAEG salt model. The survey area for this study is indicated by the dense concentration of source events (+'s).

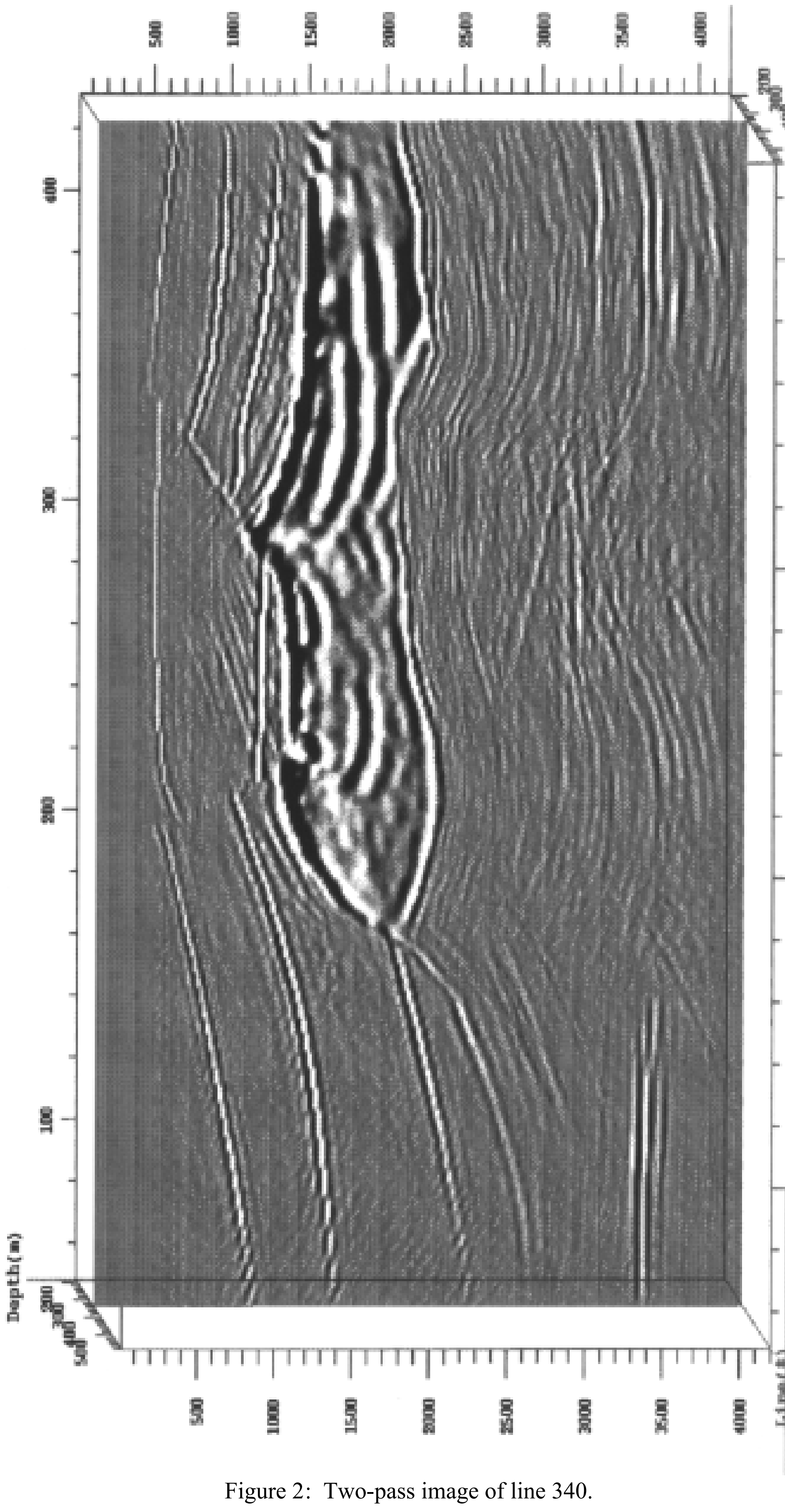

Figure 2: Two-pass image of line 340.

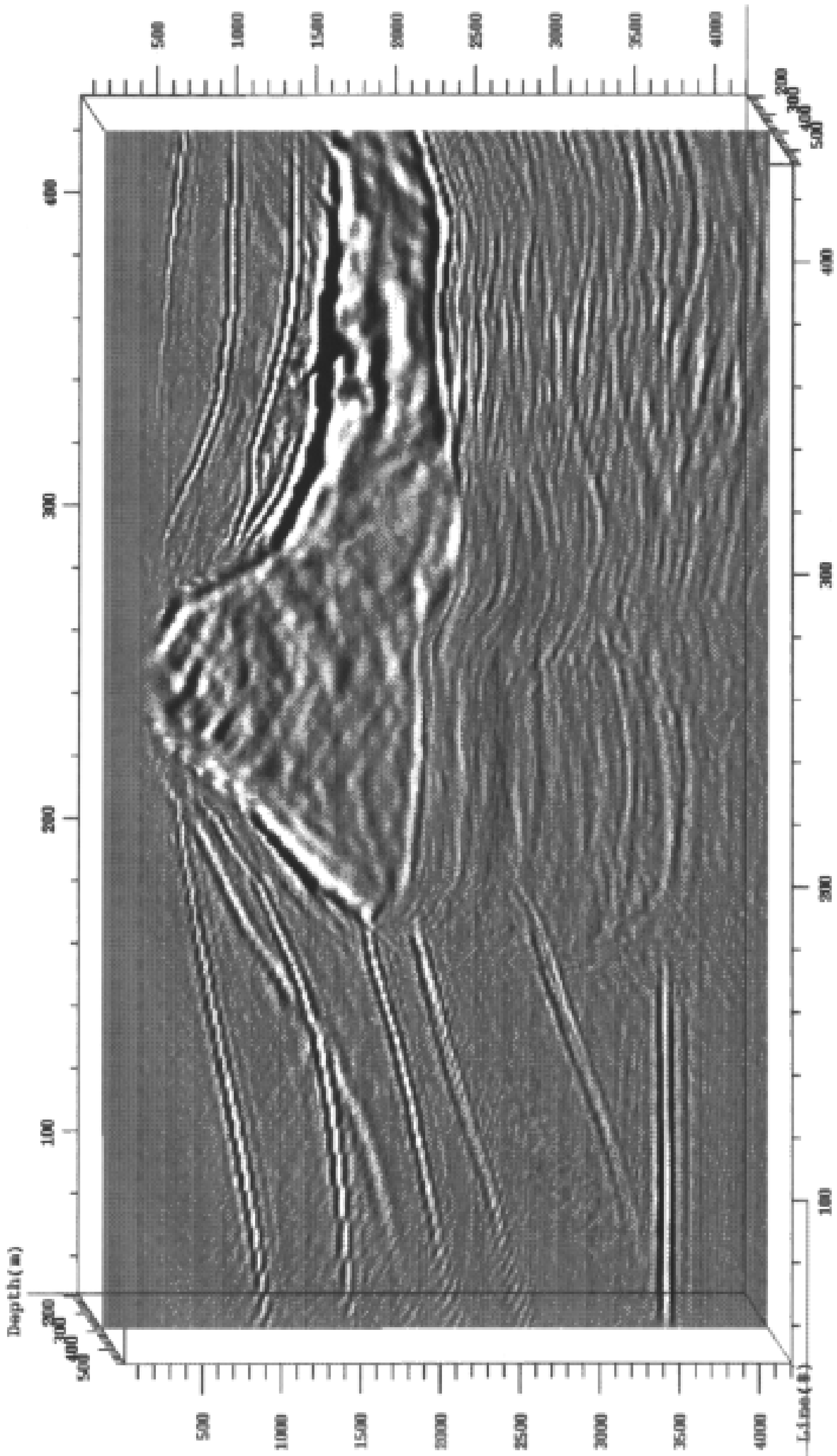

Figure 3: Two-pass image of line 385.

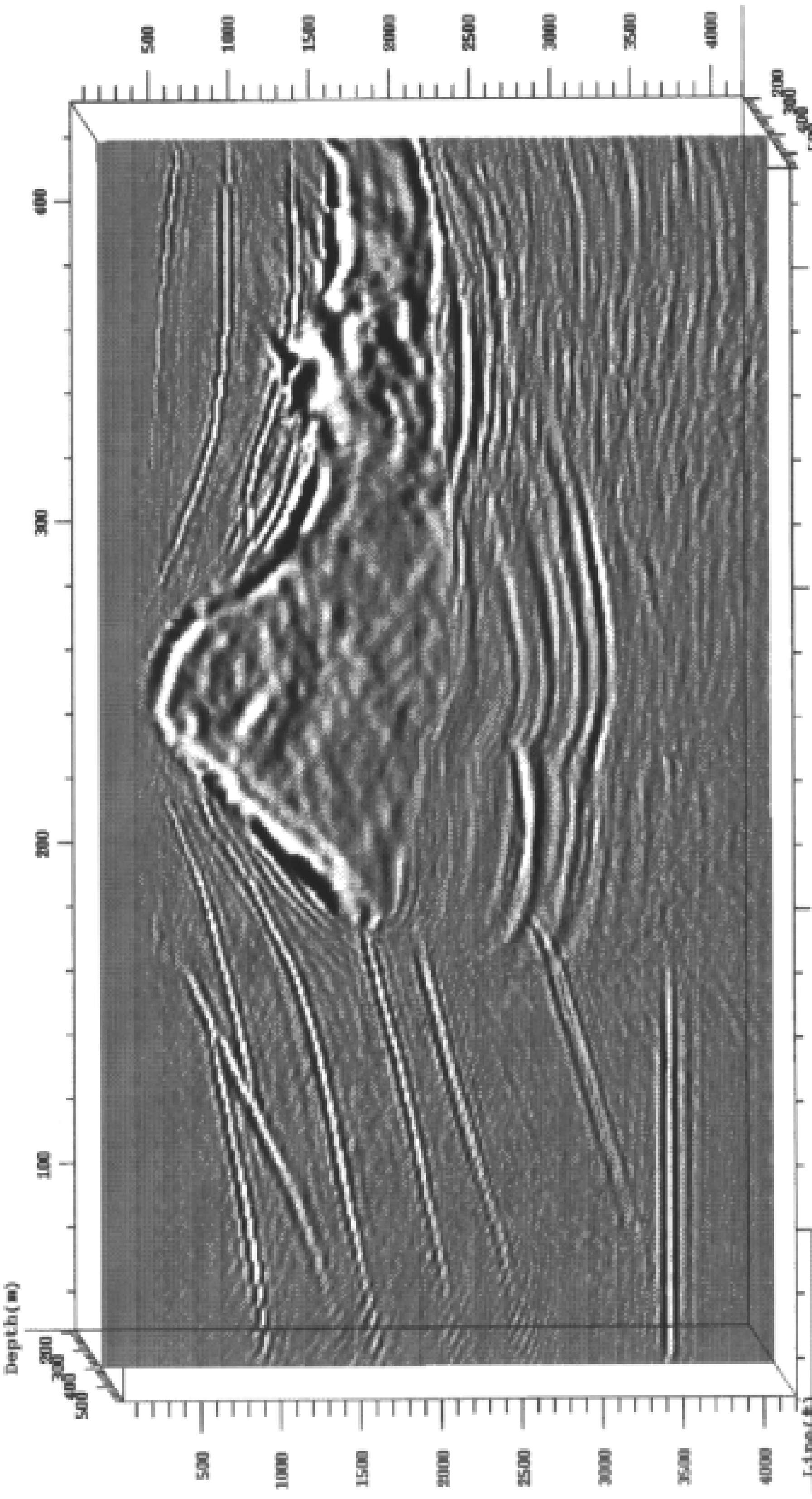

Figure 4: Two-pass image of line 400.

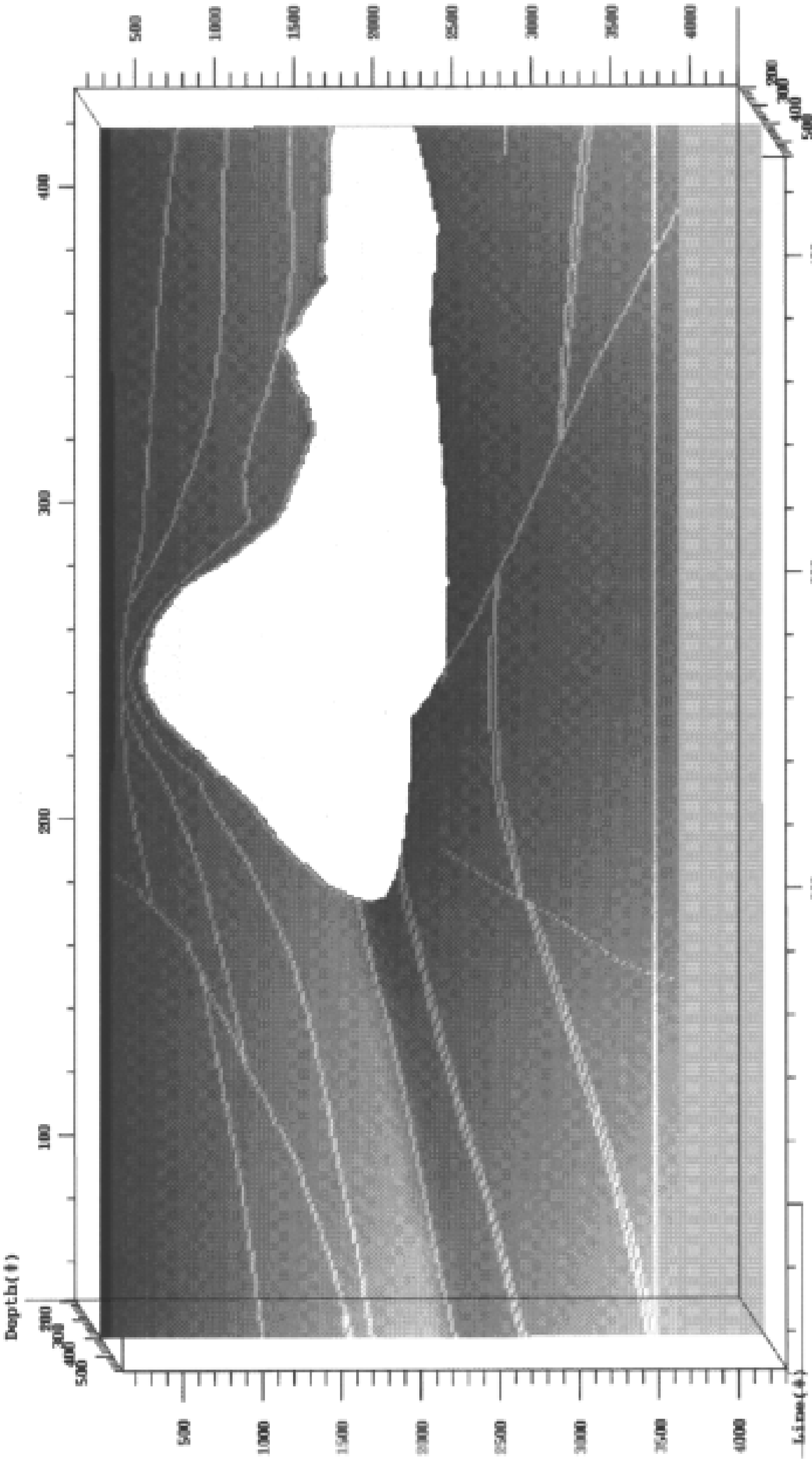

Figure 5: Velocity model for line 400.

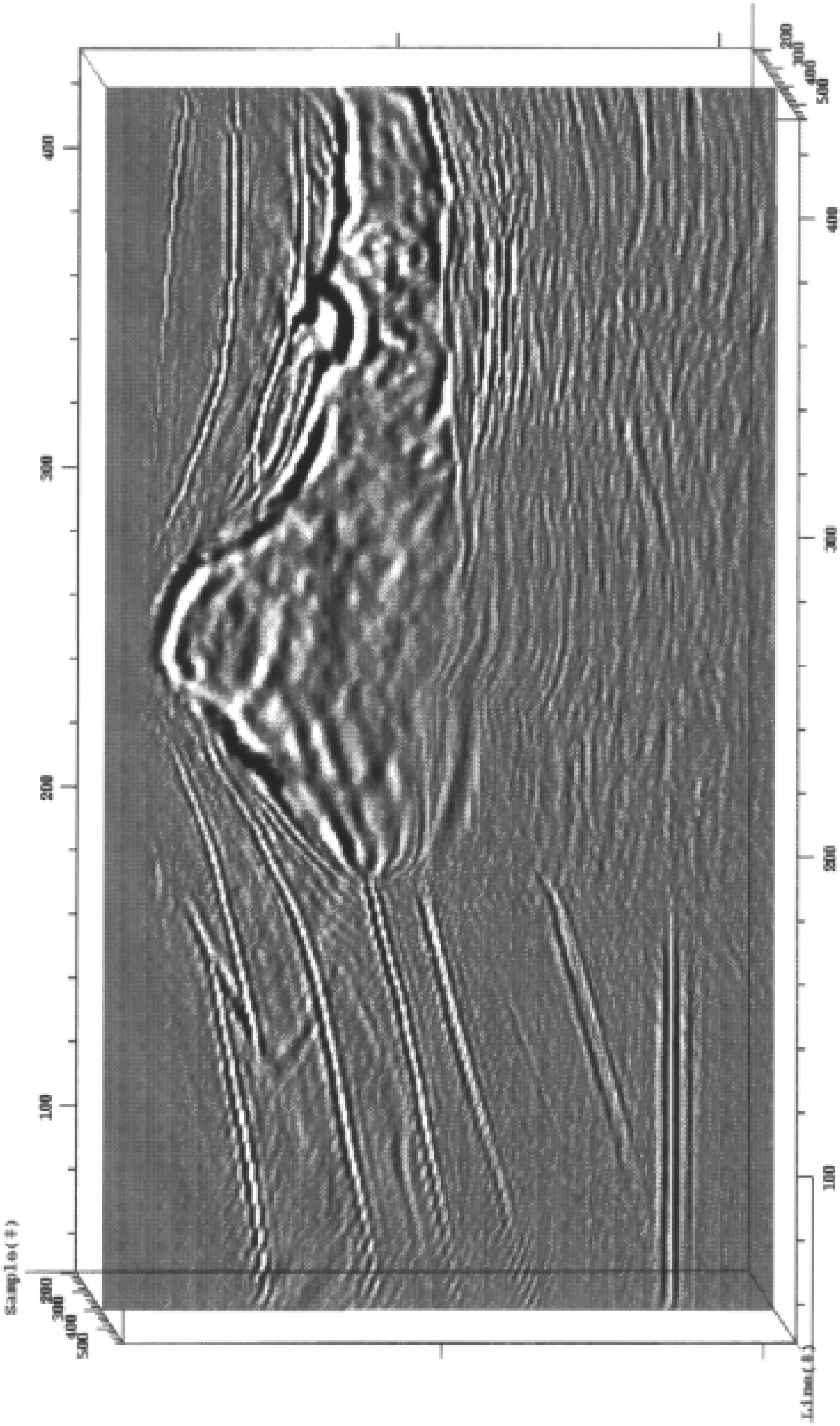

Figure 6: Two-pass image of line 400 using salt “contaminated” velocities.